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A Colourful Past: A Re-examination of a Swedish Rococo Set of Furniture with a Focus on the Urushi Components

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ABSTRACT
Two artefacts in royal custody, an étagère (inventory number HGK401) and a writing desk (inventory number HGK1249), that display specific aspects of Swedish Rococo furniture in an exciting combination, are re-examined through scientific means. Microscopy of cross sections, wood species identification, scanning electron microscopy with energy dispersive X-ray spectroscopy, X-ray fluorescence microscopy, and pyrolysis-gas chromatography-mass spectrometry analyses reveal some of their physical and chemical characteristics. The results show that the original wood includes hinoki, and the actual urushi ware originates from at least two different artefacts, of which one was made in Japan. A specific mixture of saps hitherto only confirmed on historical Ryukyu Island urushi artefacts was detected. Blue coloured urushi is verified.

Terminology
Most publications written in English translate ‘urushi’ as ‘lacquer’. The traditional materials are known as urushi in Japan and qi in China. Lacquers in Europe are entirely different substances, technologies, and traditions (Murose in Matsuda 2019, 7). The words have different etymologies and are associated with different connotations, the substances have different origins and chemical compositions, and their deterioration paths are therefore dissimilar. In this paper and in the absence of a better word, the term urushi covers Asian products made from either urushiol, laccal, thitsiol, or a mixture of saps. The saps are tapped from either the Toxicodendron succedanea (laccol) that grows mainly in Vietnam; or the Gluta usitata (thitsiol) that grows...

The term lacquer covers transparent coatings made with resins dissolved in alcohol or volatile oil, a mainstream Occidental arts and crafts technology. The term japanning defines a European coating technology, in which locally available materials were used to imitate urushi wares from abroad. Japanning was frequently black or red but occasionally blue, green, yellow, or white (Brunskog 2003, 61).

**Nils Dahlin and a set of furniture in his production**

For most of his life, the Swedish cabinetmaker Nils Dahlin (c.1731–87) resided and worked in Stockholm, but in periods also in Paris. During his early career, he worked in a style which was linked closely to contemporary French ideals. He became a master at the age of 30 (Fataburen 1927, 55; Henschen and Blomberg 1961, 579; Erelöf 1989; Söderström 1997, 313), or as ‘painted with Chinese lacquer’ (Sylvén 1996, 83–87). Furniture such as this was highly valued in itself. However, it was also intended to increase the prestige of royalty, so-called conspicuous consumption to display wealth, power, and intellectual capacity worthy of a reign (Laine, manuscript 2019).

Initially, the exotic, costly veneer on the étagère and the writing desk was polished and coated. Surface treatment was the standard procedure and served to bring out the best in the structure and the natural colours of the veneer wood. During the mid-eighteenth century, coatings on veneer were typical of vegetal resins in an alcohol or a volatile oil solution. Shellac was probably never the only film-forming substance since it created too much redness, and a clear lacquer was the ideal (Roubo 1769–75, vol. 5, p. 279). A very high gloss was not in vogue during the time in question, but became fashionable later (Brunskog 1982, 22, 30; Fontana, Hellwig, and Martius 1999, 10–12). Handsawed, contemporary veneers are in their original thickness estimated to be 1–2 mm, comparable with the thickness recorded of many urushi panels (Nagashima 2014, 110–112). Attaching urushi sheets to a wooden

Figure 1. The writing desk and the étagère signed Nils Dahlin 1771, commissioned for the Swedish queen Lovisa Ulrika. Inventory No. HGK1249 and HGK401 respectively. © Kungl. Hovstaterna, foto Alexis Daflos, 2007.
body would meet the same difficulties as in veneering. The problem of anisotropy between components with different directions is always present. Skilled cabinetmakers knew how to orientate radially cut wood to compensate as much as possible (Roubo 1769–75, vol. 5, pl. 295) (see Figures 2 and 3). Other contemporary, similar furniture made in the French style or by French joiners, and known to have urushi panels are often also japanned and the interface between the two types of coatings disguised with ormolu fittings (Hagelskamp, Heginbotham, and van Duin 2016, S3–S91).

Previous research on Dahlin’s furniture and matters of discourse

Some of the assertions related to the manufacture of this specific furniture have become more or less mythological with time. The issues under discussion, as compiled from scholarly research and other publications, concern whether the black looking areas with motifs in gold, silver, red, black, and mother-of-pearl represent European or Asian technology. If made according to Far Eastern traditional technology, urushiol, thitsiol, and laccol, Asian process, and structure would be expected. Petisca et al. (2016, S3–S89) has reported on ways to hasten the manufacture of Chinese export wares, in which the ground and coating layers are modified compared with the traditional, domestic structure. Both Petisca et al. and Webb (2000, 38) have reported that Chinese export artefacts made in the nineteenth century had a simplified coating structure which corresponds closely to coatings on other artefacts in Swedish public collections. The original coating structure on one of the boards of the wall panelling in the red room, Chinese Pavilion, Drottningholm, shows a two-layer ground made of coarse-grained material, separated by paper, covered with a two-layer coating, corresponding to the structure reported by Hagelskamp,

Figure 2. Overview of the black-looking areas on the étagère, front and both short sides, inventory number HGGK401. (Photo: Brunskog 2018).

Figure 3. Overview of some of the black-looking areas on the writing desk, one of the long sides and both short sides, inventory number HGGK1249. (Photo: Brunskog 2018).
Heginbotham, and van Duin (2016, S3–S93). In Japan, since pre-historic times, multi-layered urushi ware shows advanced manufacturing techniques used parallel with much more straightforward ways of production (Kuraku 1998, 47). During the second half of the eighteenth century and the introduction of commercial goods, there followed a change also in the production of Ryukyuan urushi ware, with more straightforward techniques (Tokugawa 1995, 228). Perhaps the level of complexity was not a matter of knowledge but rather a consequence of individual choices and demand-driven.

Another issue is the question of whether components were imported to Europe and re-exported to Sweden, or imported directly to Sweden, or indeed if the half-finished furniture was sent overseas on a return trip to the Far East to be decorated (Söderström 1997, 313). Other contested issues include whether or not lacquer workshops existed in Europe during the period in question (Lagerquist, 1949 quoted in Söderström 1997, 313; Henschen and Blomberg 1961, 580; Lagerquist cited in Erelöf 1989, 1; Sylvén 1996, 83–87). Some scholars claim that such workshops could make actual Asian technique artwork often denoted as ‘true lacquer’. However, this is mostly discounted by other scholars, since saps did not withstand the long sea transport without curing and attempts to grow sap-producing trees in Europe failed. Therefore, the hypothesis remains speculative.

On the contrary, Paris is thought to be the centre for experiments on how to reuse smaller or larger fragments of urushi ware on European products based on numerous examinations of cross sections sampled from bent-coating furniture (Hagelskamp, Heginbotham, and van Duin 2016, S3–S91; Characterization of Asian and European Lacquers 2010). In general, the process of gluing veneer in a geometrical pattern onto a sub-structure would start in the middle of each surface. After the first piece was glued, the rest would be glued one by one piece until the surface was covered, extending in all directions simultaneously to maintain control over the symmetry and at the same time minimise the risk for warping. Adjustment of the precise shapes and sizes would be made after each piece, or as appropriate, to trim edges and to remove excess veneer (Roubo 1769–75, vol. 5, pl. 295). The suggested procedure to send half-finished artefacts to and from the Far East would require that the final veneering was done after the decorative middle part was completed, as well as that the desired final design had to be known to the foreign artisan.

Scholars disagree on whether some urushi ware – initially made for another purpose – was dismantled to supply material for this set of furniture and from where such elements may have come. It has been suggested that a folding screen that used to belong to the royal household is a possible source for the desk and the étagère in question, based on superficial similarities with other artefacts in royal custody, as well as documentary indication (Gyllensvård quoted in Erelöf 1989, 1). It has been assumed that most of the sheets from that specific screen were split into halves and then framed between wainscoting in the yellow room in the Chinese pavilion, Drottningholm. Comparison of the étagère and the panels in the yellow room indicates both differences and similarities. The elements of the motives are quite similar, but the polychromy is different. The present condition differs, the panels in the wainscot being worse with exfoliating coating, while the opposite might be expected (see Figure 4). It is assumed that the process of attaching such panels onto a double-curved surface included moisture, heat, and pressure when the urushi was bent over a three-dimensionally shaped wood body, and the outmost surface thereby was stretched or compressed.

Another hypothesis is that Dahlin used sheets left over from both the red and the yellow room (Odlinger Haubo 2008, 234). The structure on the panels in the red room displays a two-layer ground on wood, separated or reinforced with an intermediate paper layer, and covered with two coating applications. One of the panels with a damaged corner displays both the original Asian coating and the secondary nineteenth-century japanning. As can be seen, the reverse sides of the framed sheets in the wainscot is wood. However, this backing material is assumed to have served merely as protection during transport from the Far East to Sweden (Sylvén 1996, 86). Another hypothesis states that the assumed support material used for the black areas of the étagère and the desk was some canvas, and is justified by the idea that painted canvases were perhaps mounted on stretchers during transport and then removed (Sylvén 1996). From a cabinet making technology point of view, the fact that the furniture has double-curved surfaces in the Rococo style raises questions about how formerly flat members of construction could be attached at all. A flexible material such as a canvas fits better into that supposed procedure of manufacture. Another option for a flexible body material has recently been reported by Hagelskamp, Heginbotham, and van Duin (2016). Leather has been confirmed as the substrate for urushi coating and reused on a pair of corner cupboards made by Jacques Dubois (1694–1763) Paris, France, c.1755. Leather is a well-known substrate (shippi) for urushi since ancient time but commonly seen as core in Japanese and Korean armour (Webb 2000, 19). Nevertheless, another option is ‘dry lacquer’, i.e. urushi applied on paper or textile fabric (kanshitsu). However, such artefacts are generally coated on both sides, making them very thin and extremely difficult to split parallel with the pictorial planes.
Potential trade routes for urushi ware

Suppose we assume that earlier hypotheses about European workshops being capable of making urushi work are incorrect, and urushi ware could neither have been manufactured in Europe nor in Sweden. Extensive, previous, scholarly studies show that the Dutch, British, and Swedish East India Companies contributed substantially to the Chinese and Japanese influence in Swedish residences and homes during the seventeenth and eighteenth centuries (Braw, Holmberg, and Myrdal 2011, 21, 26, 190). We can add observations that these also included much urushi ware. Such goods are recorded quite frequently in many kinds of historical documents: auction catalogues, toll registers, personal correspondence, and cargo declarations.\(^2\)

Furthermore, the auction catalogues show that urushi ware, such as different kinds of boards either square, round, or oval and with diverse patterns, including mother-of-pearl, frequently were on sale. Many boxes and coffers were sold in sets of maybe two, three, or more. Listed folding screens had five, six, or eight sheets. Between 1733 and 1759, the Swedish East India Company auctions represent in total only the cargos brought home during 31 expeditions, a little less than a quarter of all expeditions, and comprise 3324 more or less two-dimensional urushi ware (see Table 1). Suppose these years are representative of all ladings. In that case, the total amount of potential material for making furniture similar to the writing desk and the étagère in question must have been considerable. A frequently cited image in the Victoria and Albert Museum collection (online catalogue, entry: inventory number P.35-1926) may illustrate a diversity of imported goods. The documentary sources support the presumption that urushi ware of many kinds, in high number, and widely different sizes were imported during the period of interest, and that there is little to contradict their reuse in various ways.

In addition to auction catalogues, urushi ware was noted in toll account registers, which are an essential source for research on trade, transport, production, and consumption in Europe, and cover commodities such as Indian, Chinese, and Japanese goods. Whether the inflow of urushi ware used for cabinet making in Sweden also arrived through secondary trading with Asian commodities from other European centres, in Portugal, Spain, France, the Netherlands, and England seems entirely plausible based on the many entries in the Sound Toll Database online register (The Sound Toll Database).

A third possibility for import of urushi ware to Sweden during the period in question was via officials
or journeymen who travelled in Europe for various reasons. As stated above, Dahlin was inclined to French ideals (Falck 2008, 7–9). Information on current trends might also have been conveyed to Dahlin by individuals responsible for the management of the royal estates since he received commissions from the royal household (Söderström 2009, 297–328; Alm and Millhagen Adelswärd 2010, 200–201). For the reconstruction of the Royal Palace – from 1697 to the end of the 1750s – many French journeymen received commissions and worked for periods in Stockholm (Hinners 2012, 19–20). Some French artefacts, such as in the collections at the Louvre and Musée Carnavalet in Paris, The Victoria and Albert Museum in London, Rijksmuseum in Amsterdam, Kunstgewerbe Museum in Berlin, and Museu Calouste Gulbenkian in Lisbon, are visually similar to Dahlin’s furniture. As stated above, Dahlin travelled as a journeyman to Paris, so it cannot be excluded that he purchased artefacts or fragments of urushi ware which he already had learnt how to use and had seen on furniture made by other masters.

Paris was at that time not only a centre for modernity it was also a centre for commerce. As observed, some museum collections (Musée des Beaux-Arts de Dijon, Dijon; Musée Antoine Vinenel, Compiègne; and the Louvre, Paris) contain fragments of urushi ware, some only one-sided, others two-sided (Nagashima 2014, 19, 21–24). The former can be as thin as 7 mm, with a more or less equal thickness of coating and substrate. Cabinetmakers had the skills and capacity to produce thin veneer, even from hardwood, by sawing thin slices either across or along the grain – less than 2 mm as standard. Most of the fragments studied by Nagashima display a wood substrate (2014, 20, 23) (see Figure 5). During the period in question, such material was available for purchase at the ‘les marchands merciers’. These entrepreneurs are said to have sold everything but made nothing, i.e. merchants working outside the guilds, often specialising in fashionable, exotic, and extravagant products.

Hence, it is not so far-fetched to assume Dahlin had heard of or even handled urushi ware either in France or in Sweden. He might have been able to recognise the appearance of various types of urushi ware, but that has to remain unverified. However, it appears certain that he was acquainted with what at that time was called Japaniskt lacverck (Japanese lacquer) (see Figure 6). Therefore, there is nothing to substantiate the idea of the black-looking panels being japanning.³

One way to understand the payment that Dahlin received is to estimate how much of certain commodities he could have purchased for that sum and then translate it into the value of the same products today. In the 2019 consumers’ price index, that value is 252,748 Swedish kronor (SEK). The payment can also be compared with the average wage per hour of an industry employee in 1771. Today, the same hours are equivalent to 8,171,026 SEK (Edvinsson and Söderberg 2011). Neither of these estimates makes it more or less plausible that the set of furniture went to and from the Far East. Nor does it indicate whether the urushi components were purchased in Europe or Sweden, or whether a workshop in Europe could make the urushi ware either in France or Sweden. It might have been able to recognise the appearance of various types of urushi ware, but that has to remain unverified. However, it appears certain that he was acquainted with what at that time was called Japaniskt lacverck (Japanese lacquer) (see Figure 6). Therefore, there is nothing to substantiate the idea of the black-looking panels being japanning.³

Contemporary furniture with similar decorations

Scholarly research on similar kinds of furniture has noted that several French masters had the skills necessary to produce high-quality furniture with double-curved surfaces. Such furniture sometimes reused urushi ware to cover the surfaces either entirely or in

Table 1. Documentary evidence of the trading in urushi wares traced in the digitalised auction catalogues of SOIC, available online at the Swedish National Archive (RA).

<table>
<thead>
<tr>
<th>Year</th>
<th>Case, small box</th>
<th>Chinese painting</th>
<th>Tea board</th>
<th>Folding screen</th>
<th>Large box, chest</th>
<th>Coffer</th>
<th>Table, table top</th>
<th>Watch-case</th>
<th>Toilet</th>
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Notes: The table shows the number of items registered under the headings ‘Lacquerade Wahror’ (urushi wares), ‘Diverse Waror’ (miscellaneous wares), and ‘Lacquer’ or ‘Diverse Waror til exportation’ (urushi, or miscellaneous ware for re-export) distributed in cargos landed between 1733 and 1759.
combination with japanning or veneer wood. Ormolu fittings were typically used to hide any gap or mismatch between the Asian and the European components to produce a perfectly smooth and attractive result.

Hagelskamp, Heginbotham, and van Duin (2016, S3–S93) discusses the dimension of *urushi* components and concludes that *urushi* on the doors of a French commode, measuring approximately 40 cm square each, can be fragments retrieved from a folding screen. Individual panels of Chinese lacquer screens are rarely wider than 55 cm. As noticed on the French commode made by Delorme (inventory number BK-16652), the *urushi* covering the two drawers originally formed a single sheet approximately 80 cm wide and 50 cm high (Hagelskamp, Heginbotham, and van Duin, 2016, S3–S94). The panels in the red room at the Chinese Pavilion, Drottningholm, are even larger; 107 cm wide, 59.5 cm high, and ca.

**Figure 5.** Examples of *urushi* ware fragments at present in French museum collections, similar to *urushi* ware assumed to have been on sale at the *les marchands merciers*, in Paris. The top-row shows a split fragment with *urushi* on one face only, whereas the other images show still double-sided *urushi* ware (Nagashima 2014, 20).
1.7 cm thick, whereas the panels in the yellow room are about 213.5 cm high, 59 cm wide, and 0.8–1.2 cm thick (Brunskog 2007).

In conclusion, the main point to make is that the Swedish East India Company, other East India companies, other trade routes, or individuals travelling around Europe carrying personal luggage, could supply large quantities of urushi ware. Other inter- or intra-continental distribution channels might also have been partially responsible.

**Figure 6.** The bill of debt on which Dahlin signed the payment for the desk (*skrifbord*) and the *étagère* (*Serpapie*), issued by the Queen’s account office, undated but assumed to be written in 1771.

**Figure 7.** Sampling positions on HGK401 *étagère* (left) and HGK1249 desk (right) respectively.

<table>
<thead>
<tr>
<th>Table 2. Sample location and methods of analysis.</th>
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*USB microscope photography.
**Light microscopy.
***Morphology of wood.
Experiments

Samples
The sampling was restricted to seven small-size specimens, all collected from behind key plates. This sampling was from two distinct areas, one on each piece of furniture (see Figure 7). Three specimens were sampled at the left-hand side of the étagère and four from one of the desk’s drawers. The specimens are detailed in Table 2.

Instrumentation

USB microscope photography
For close-up images of surfaces before sampling, a handheld Dino-Lite Digital Microscope Pro model in the AM/AD 411X series was used together with the software DinoCapture 2.0 supplied from the manufacturer. The microscope connects to a laptop computer with Microsoft XP software.

Stereomicroscope photography
Before analysis and embedding, all specimens were documented on both faces using a stereomicroscope Nikon SMZ1000 (Japan), Plan Apo 1x lens, oculars C-W 10x/22. Images were captured with a DinoEye eyepiece camera AM4023CT/R4 1.3 megapixel resolution.

Preparation of cross sections and light microscopy
Specimens aimed for microscopy and epi-fluorescence observation were embedded in cold mounting epoxy resin Epofix, mixed with a hardener supplied by Struers. The epoxy cured overnight. Subsequent grinding and polishing were done on a manual Struers Lab Pol-5 using waterproof silicon carbide grinding papers grit 220, 320, 500, 800, 1200, 2400, and 4000 stepwise and a few minutes on each grit. The Nikon Optiphot polarising microscope with an effective magnification 50–400x was equipped with trinocular 10x eyepiece tubes, epi-bright/darkfield illuminator, halogen lamp, and plandachromat objectives 5x–40x. The microscope was used in combination with reflected UV-light for epi-fluorescence observation, with a Nikon super-high-pressure mercury lamp model HB-10101AF. Images were captured with a Nikon DS-Fi2 camera and Nikon TV-lens C-0.6x and processed with Nikon Image Software Elements D version 4.20 to show the best possible resolution, depth of focus, and undistorted images.

Scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDX)
SEM-EDX analysis used a LEO 1455VP (Zeiss) scanning electron microscope, with a tungsten filament. The SEM was equipped with an EDS (Oxford instruments) with INCA 400 software. Images were collected and point analyses of elements performed in variable pressure (VP) vacuum mode, EHT 15 kV and probe 300–470 pA, as well as mapping of elements over larger areas, without further preparation of the specimens.

X-ray fluorescence microscopy (XRF)
XRF microscopy analysis was performed at normal atmospheric pressure with current 50 kV and 1.0 mA in the Horiba Scientific XGT-5200 Analytical X-ray Microscope with high spatial resolution, from 1.2 mm down to 10 µm.

Pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS)
Direct Py-GC-MS measurements were performed with a vertical microfurnace pyrolyser PY-2020iD (Frontier Lab, Japan), an HP 6890 gas chromatograph, and an HPG 5972A (Hewlett-Packard, Ltd.) mass spectrometer. A stainless steel capillary column (diameter 0.25 mm × 30 m) coated with 0.25 μm of Ultra Alloy PY-1 (100% methyl silicone) was used for the separation. The specimen (50 µg) in a platinum sample cup was introduced into the furnace at 500°C, and the oven was...
programmed to provide a constant temperature increase of 12°C per min from 40°C to 320°C and held for 10 min at 320°C. The flow rate of the helium gas was 1 ml min\(^{-1}\). The injector was used with a split of 50:1. The MS ionisation energy was 70 eV (El-mode). Data were analysed with Agilent MSD Chemstation software (Iidei et al. 2018, 1–5; Takahashi et al. 2018) and all pyrolysis products were identified from an interpretation of their mass spectra.

**Result and discussion**

The presentation of results follows the stratigraphy of the making process bottom-up. Figure 8 summarises the results from observations and analyses in a condensed form.

On sampling, the intention was to cover as much as possible of the present materials. However, wood from the original body was unpredictable and only obtainable once. To begin with, it was not clear whether wood was the original support material or not. It was also uncertain if any wood remained, and if it did, to know precisely where. On sampling, only tiny pieces were removed. Any ambition to spot original wood seemed almost impossible to achieve. It was a pure lucky circumstance that it was the case. Figure 9 shows the wood from the étagère HGK401 was cut in all three principal directions. The wood is identified as hinoki, an evergreen coniferous tree *Chamaecyparis obtusa* (Siebold et Zucc.) Endl, also called Japanese cypress (Noshiro 2018). This species is indigenous in Japan only and is known for being used as body material for thousands of years (The Wonders of Urushi, 2017, 22). Therefore, identification of hinoki is a strong indication of the urushi ware on the étagère being made in Japan. The hypothesis that the furniture was sent abroad half-finished to have the urushi components made on-demand either in East Asian or in Europe is as a result of this refuted. If that had been the case, no original wood would remain on the reverse sides of the panels. There is no evidence of textile fabric or leather as the substrate in this or any other specimen from the two pieces.

The ground on the étagère HGK401 appears to be a four- to a seven-layer structure. The observed wood increases the validity of these estimates. There is no indication of an intermediate paper or textile fabric, the colour is uniform brown-greyish with single white rounded particles, and interpreted as layers rich in urushi (see Figures 10 and 11). The particles seem to be similar in all layers, as interpreted by SEM (see Figure 12). Elements detected by SEM-EDX in specimens HGK401 Nos. 1–2 include aluminium (Al), barium (Ba),

**Figure 9.** End-grain, tangential, and radial section of Japanese cypress (*hinoki*) specimen from HGK401.

**Figure 10.** Cross section of specimen HGK401 No. 1, after processing. The foundation seems to be a four-layer (or maybe a six-layer) structure. VIS (left) and UV light (right).

**Figure 11.** Cross section of specimen HGK401 No. 3. Note the six-layer or seven-layer ground structure, being light brown-greyish in a visible light darkfield, and showing very low fluorescence emission. VIS (left) and UV light (right).
calcium (Ca), lead (Pb), magnesium (Mg), phosphorus (P), silica (Si), and sulfur (S) (see Figure 13). These elements, distributed mostly in the ground layers, are interpreted as filler. SEM images show rounded particles with distribution in size. Such observations support the interpretation of a natural clay or earth compound, rather than a synthetic substance. The same images show that the structure and composition are the same in all ground layers. Calcium-rich areas coincide with the white, larger particles.

SEM-EDX confirmed the elements aluminium (Al) and silica (Si) in the same specimen (see Figure 14). All atoms mapped indicate a mineral, but the composition is not the same as in HGK401. The intermediate layer is paper, but the kind of paper fibre is unknown. However, the paper is thin and shows an open structure, resembling of traditional washi, kozo, or gampi. In cross sections the shape of the paper fibres are visible, and the compounds detected by SEM-EDX in the same zone are carbon (C), and oxygen (O) as would be expected in vegetable fibres (see Figure 14). Py-GC-MS data confirmed cellulose pyrolysates.

The observations indicate a traditional urushi ware ground on the étagère. The ground on the desk shows affinity with what has been assumed as a simplified urushi ware structure.

Over the ground, a two-layer coating is applied on both the étagère HGK401 and the desk HGK2149. The two-layer structure is visible, especially under ultraviolet (UV) light (see Figures 11, 15, and 16). The coating film looks brown and semi-transparent, with very even interfaces, and shows low UV fluorescence, all signs interpreted as typical urushi characteristics. Since there are no traces of a black pigment or
colourant in the actual coating layers, the black appearance might be due to soot applied after the ground layers were finished but before clear urushi was applied (see Figure 11). This type of structure is interpreted as carbon black (soot). Soot is a known way to make black urushi, traditional before the mid-eighteenth century in both China and Japan and charcoal (wood ash) is one of the oldest pigments, used already in pre-historic times.

Py-GC-MS data from the étagère HGK401 shows characteristic peaks. The $m/z = 108$ chromatogram obtained by direct pyrolysis GC-MS detected 3-butyl phenol (4), 5-pentyl phenol (C5), 3-hexyl phenol (C6), and 3-heptyl phenol (C7). The compounds detected were only substructures of urushi, probably due to the progressing degradation. Py-GC-MS data of HGK401 did not yield sufficient mass spectral data due to the degradation of the coating. Urushi films are vulnerable to ultraviolet rays, and if exposed for a long time, the film will oxidise and deteriorate. Our analytical sample was analysed by using a piece of coating peeled from the main body. Therefore, the samples for analysis were limited to exfoliated samples, and the amount was conservatively small.

Figure 14. SEM-EDX mapping of elements in the cross section specimen HGK1249 No. 2. The detection of aluminium (Al), and silica (Si) indicates a mineral substance as the filler in the ground.

Figure 15. Cross section of specimen HGK1249 No. 1. Note the intermediate layer between ground layers with a fibrous structure. SEM (left) and VIS light (right).
However, thermal decomposition products of the specimen from HGK401 showed characteristic mass spectra of C4 to C7, sufficient to confirm the presence of urushiol. Data published in 2006 (Lu, Yoshida, and Miyakoshi 2013, 370–376) was compared with these data and helped in the interpretation. The conclusion is that compared with a standard *T. verniciflua* *urushi* film, the coating material on HGK401 originates from *T. verniciflua* lacquer tree (see Figure 17). The outcome indicates that the étagère was coated with sap collected from trees which are the main sap-producing species in Japan, China, and Korea. Lacquer trees, a member of the family of *Anacardiaceae*, has more than 73 genera and 600 species all over the world. However, most of them grow in the subtropical region of Southeast Asia. The sap, in Japan called ‘raw urushi’, is collected from lacquer trees. The three main sap-producing species are typical for different regions, as mentioned above. Thus, the sap’s main component

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**Figure 16.** Close-up of cross section of specimen HGK1249 No. 1, same as in the previous figure. Note the darker intermediate layer between the ground layer and film former, the 2-application structure in the film former, and the white-bluish fluorescence emission colour of the top layer. VIS (left) and UV light (right).

**Figure 17.** Py-GC-MS chromatogram at *m/z* 108 of specimen HGK401.

**Figure 18.** Py-GC-MS chromatogram at *m/z* 60 of specimen HGK401.
is also an indication of where it was harvested. Although the sap tapped from *T. succedanea* has a slower drying speed than that from *T. vernicifluum*, the colour, gloss, and surface smoothness of the film is lower than those of corresponding Japanese and Chinese films (Lu, Yoshida, and Miyakoshi 2013; Lu and Miyakoshi 2015). Also, oil was detected by the Py-GC-MS analysis of a specimen from HGK401, and confirmed by the result m/z 60 (see Figure 18). The drying oil is interpreted as a means to reduce the lustre of the final coating.

Furthermore, retainin (C\textsubscript{18}H\textsubscript{18}, molecular weight 234) and pyrene (C\textsubscript{16}H\textsubscript{10}, molecular weight 202) were detected (see Figure 19). These are the typical pyrolysis products derived from charcoal. In general, powdered charcoal added to urushi sap strengthened the substrate or acted as a black pigment, as referred to above (Shin, Hajime, and Chuichi 2011, 346–349; Idei et al. 2018, 1–5).

The same result also applies to Py-GS-MS data of HGK1249 in which cuparene (C\textsubscript{18}H\textsubscript{22}, molecular weight 202), retainin (C\textsubscript{18}H\textsubscript{18}, molecular weight 234), pyrene (C\textsubscript{16}H\textsubscript{10}, molecular weight 202), and fluoranthene (C\textsubscript{16}H\textsubscript{10}, molecular weight 202) were detected. Direct Py-GC-MS of a specimen from HGK1249 shows m/z 108 a characteristic of standard urushi films, having peaks of urushiol and laccol appearing at 3-heptylphenol (C\textsubscript{7}), 3-nonylphenol (C\textsubscript{9}), 3-pentadecylphenol (C\textsubscript{15}), and 3-heptadecylphenol (C\textsubscript{17}). The obtained chromatogram is compared with standards of *T. vernicifluum* and *T. succedanea* saps, shown in the red and blue line (see Figure 20). The conclusion is that the urushi panels on the desk were made with a mixture of saps collected from two wood species, and in extension, that the saps were harvested in Japan, China, Korea and Vietnam respectively. *T. vernicifluum* grows in Japan, China, and Korea, whereas *T. succedanea* is a sumac tree that grows in Vietnam (Honda et al. 2008, 68–75). Saps from *T. succedanea* tend to cure slowly when used in Japan. Therefore, by adding *T. vernicifluum* sap from Japan or China, the polymerisation can be accelerated, as reported by Anzai et al. (2014, 130–140). Experimentally, a 3:10 wt % urushiol/laccol mixture showed good drying properties and film hardness. Examples of such blends have been found on historical Ryukyu artefacts, Okinawa Prefecture, Japan (Honda et al. 2015, 41–45). Besides using locally available sources for sap, there is documentary evidence of the import of large volumes of sap from Southeast Asia to Nagasaki, Japan, recorded during the middle of the seventeenth century (Kitano et al. 2008, 37–52; Honda et al. 2010,
However, as far as is known, of artefacts made with a mixture of these two saps, none exists in mainland Japan. Only a few are Ryukyu island urushi ware from the past kingdom such as a green Zen dinner tray with chinkin designs in the collection of Urasoe Art Museum, Naha, Okinawa (Miyakoshi, Miyazato, and Honda 2019, in press). This study might be the first to confirm an example of such urushi ware in Europe.

Furthermore, Py-GC-MS detected oil, dehydration sugar of polysaccharide, glue, and indigo in a specimen from HGK1249. The oil and the dehydration sugar show in the result at m/z 60 (see Figure 21). The glue detected shows at m/z 67, m/z 81 and m/z 154 (see Figure 22). The indigo detected shows at m/z 262 (see Figure 23). Urushi sap is sometimes mixed with a drying oil to reduce the gloss of the final coating. Indigo dye is a plant extract which produces a deep blue colour. Its presence in the coating is interpreted as a colourant. Cross sections of the dinner tray mentioned above showed blue spots visually interpreted as indigo (Honda et al. 2015, 41–45). Since the sap harvested in Japan dries relatively fast, it becomes dark brown. When adding Vietnamese sap, the drying is accelerated, and the colour becomes light brown (Anzai et al. 2014, 130–140). It is assumed that the Vietnamese sap was added to improve the blue hue of the final coating.

The actual urushi coating on the étagère was made from Japanese (or Chinese or Korean) sap and oil and made black with soot underlying the coating. Its appearance is assumed to have been black. The actual urushi coating on the desk was made from both Japanese (or Chinese or Korean) and Vietnamese sap, oil, and indigo, and its appearance is assumed to have been dark blue. Both were probably made initially to show reduced gloss. The decorative elements on the étagère are depicted in red, green, silver, bronze, gold, and mother-of-pearl. The decorations on the desk are depicted in red, silver, bronze, and gold. The motifs are slightly different on the two pieces; the étagère shows more variation (see Figures 1–4, 24, and 25). The particle size of the red substance underlying metal leaf or powders on the desk is small and homogenous (see Figures 26–28). Conventional red pigments in China and Japan are iron oxide red, cinnabar, and red lead. The metal is in thin flakes, of irregular shape and varying size and as powder of diverse density. The detection of copper (Cu), zinc (Zn), and gold (Au) by SEM-EDX analysis of HGK401 confirms that an alloy such as brass was used in combination with gold metal. Elements mapped in HGK401 No. 2 included copper (Cu), and zinc (Zn) interpreted as brass (see Figure 29–31). The presence of copper (Cu) and zinc (Zn) on the one hand, and gold (Au) on the other from the EDX mapping confirms the hypothesis that metal powders are made of brass and gold, and that both co-exist on the same piece of furniture. SEM images show that the metal is in the shape of flakes, more or less crumbled and dispersed over a red layer.

The specimen HGK1249 No. 2 contains leaf of gold (Au) (see Figure 32). Silver (Ag) is detected in the same specimen but much lower concentration as interpreted from SEM-EDX. In such case, the gold may be in alloy with copper or silver, or with both. However, in EDX microscopy of a fragment of the same specimen, gold was confirmed as the only component in the metal leaf (see Figures 33 and 34). Hirami or nashi jī fun is a type of metal flake. Traditionally, makie powder was sometimes sprinkled over a red ground before it cured, often made from a mixture of iron oxide red (bengara) and urushi. Gold (Au) was detected in XRF analysis of HGK1249, and the metal is present both as leaf and as powder. Hakue peony arabesque motifs in which gold leaves have been adhered with urushi is associated with Ryukyu-style food coffers.
Pyrolysis of a specimen from the desk confirmed compounds that indicate a glue. Glue can act as a binder for metal powders. Detection of iron (Fe) in the layer immediately under the metals, as in specimens HGK1249 Nos. 2–3 indicates an iron pigment, such as bengara. The proper colour, as shown in Figures 26, 27, and 29 points in the same direction, as iron oxide red often looks red-brownish, whereas cinnabar is a brighter red. Thus, cinnabar and minium are less plausible, since both mercury and lead would be detected by SEM-EDX if present in the specimens. Both pieces are decorated with gold powder in combination with other metals or alloys. Glue has been confirmed only on HGK1249 and is interpreted as adhesive for the gold leaf.

The outermost layers, as observed in some cross sections, are very uneven, cloudy, and whitish in visible light and light blue under UV light. In many traditional coating procedures, the outermost layer is uncovered, even when it is a decorative layer (with exceptions like the togidashi). Indeed, in many procedures, the intention was to leave the surface to set perfectly smooth without any subsequent polishing, by adding vegetable oil to the urushi (nuritate). However, urushi sap was
processed into many quality grades with slightly different properties in terms of drying time, gloss, and transparency (Lu and Miyakoshi 2015, 277–294). Thus, these outermost layers are secondary and a remnant of past restoration. SEM-EDX data confirmed assumed original components as well as more recent material supporting the interpretation that the furniture has undergone restoration. The outermost cloudy layer contains mainly carbon (C) and oxygen (O) interpreted as indicating an organic synthetic polymer. Such polymers correspond to restoration procedure used on other historic furniture in Sweden.

Py-GC-MS data confirms the partial structure of bisphenol and 4,4’-diamino diphenyl derivative, as shown in Figures 35 and 36. The detection of bisphenol in the specimen from HGK401 also confirms epoxy. The first patent was granted to P. Shalack in 1938, and after the mid-twentieth century, the production was commercialised. The resin reacts with a hardener, polymerises, and becomes insoluble. Due to high adhesive-ability, it has various applications. However, in contact with valuable furniture and urushi ware, its use should be very carefully considered since it may cause permanent damage.

In this study, scientific analyses are the means to add to the bulk of narratives linked to specific artefacts in royal custody. The results obtained here may not stand alone, but they open the way for a further reinterpretation of previous research and assumptions. Scholars and artists familiar with the Far Eastern coating techniques have described how sap is, and historically was, harvested and processed to be applied on different substrates following various local traditions. Traditions may be typical for distinct geographical areas or the period of manufacture or both. Firstly, Lu and Miyakoshi have shown that Chinese and Japanese products can be identified and distinguished from each other by different
means. With Py-GC-MS analysis, the sap components can be identified and therefore, by extension, so can the sap-producing wood species. Secondly, by strontium isotope ratio measurements, sap harvested on the Japanese islands can be distinguished from continental saps. However, saps were traded in large quantities between Southeast Asia, China, the Ryukyu Islands (today Okinawa), Japan, and Korea and therefore sap from a specific area is not conclusive evidence for that area as the place of manufacture. Thirdly, traditions, technical know-how, and manual skills reflect local circumstances in space and time. When and where these were used deliberately or not is always a matter of personal choice. Expertise was (and is) spread through the mobility of individuals. The distributing and retailing of such artefacts is also something that has to be taken into account. By identifying the wood species used for the body, it is probably easier to trace the place of manufacture. This method is believed to produce more valid information compared with sap identification since wood is more generally obtained locally, because wood is everywhere, bulky, and impractical to transport over long distances.

By extension, the results of this research perhaps also add to the significant amount of information on

Figure 25. Close-up images of surfaces on desk HGK1249. Examples of decorations with different powders of metals and alloys. The deterioration of the outmost surface is also visible.

Figure 26. Close-up of the cross section of specimen HGK1249 No. 2. Note the very fine-grained, uniformly red particles under the metal. VIS light.

Figure 27. Cross section of specimen HGK1249 No. 3. Indication of metal is visible on top of the red layer. Note the light white-blueish fluorescence emission colours of the red layer and the blue-greenish of top layer respectively. VIS (left) and UV light (right).
the manufacture of Dahlin’s set of furniture. Hopefully, the results lead to a better understanding of the artefacts and can support plans for their future care. It has been argued that the panels in the yellow room, Chinese Pavilion, Drottningholm, depict a scene from the Pearl River and as a consequence that the panels originally were made in China. If that is correct, it contradicts that leftovers were used by Dahlin to make the *étagère* simultaneously. The original wood indicates that the previous *urushi* artefact that provided material for the *étagère* was made in Japan perhaps with imported sap, and probably before or around the mid-eighteenth century. Thus, the original artefact was maybe already old when the assembly was done in Stockholm, Sweden. Moreover, the bill of debt strengthens the conclusion that the furniture was made in the capital. The panels in the red room, Chinese Pavilion, Drottningholm, mentioned above, are made with a wood body, and cross sections from one of these show dissimilarity with the *étagère*, in terms of the body, ground, and clear coating layers but some similarities with the cross sections from the desk. The conclusion is that no singular artefact was used to make both the wainscoting and the *étagère*.

The results on the desk are open to more interpretation than the results on the *étagère* when it comes to the origin of the *urushi* components. No original wood was spotted. A higher number of ground layers and a more complex coating structure seems to have existed in parallel with fewer layers, at least when interpreted from observations of artefacts extant in Swedish collections. Both Chinese, Korean, and Japanese have a long history of *urushi* ware manufacturing, each with its characteristics. However, there is no distinct threshold to separate Japanese from Chinese, and there are many variations. Maybe the number of ground layers reflects the anticipated end user rather than the location of the manufacturer. Maybe the export to Europe from China was more numerous compared with other East Asian countries.

Another uncertainty is the coating layers which contain sap from both Vietnam and Japan, China, or Korea. Other artefacts known to be made with the same sap mixture are historical objects from the Ryukyu Islands. During the period of interest, the Ryukyu Islands were first linked with Ming dynasty, China, followed by limited autonomy after 1609, and after that became a *de facto* part of the Shimazu domain, Japan, until the mid-nineteenth century.
The maritime empire was perhaps never independent, but part of a much more extensive network of people, goods, and cultures which flowed through the islands in all directions. Thus, a unitary entity with clear boundaries is difficult to define (Smits 2019). To evaluate the importance of the mixture of saps is thus complex, but Japan (or the Ryukyu Islands?) seems more plausible as the location for the manufacture. However, mainland China cannot be ruled out. With more material, say 20–30 mg specimens, $^{87}\text{Sr}/^{86}\text{Sr}$ isotope ratio measurement is feasible and can produce valid information on whether the sap was harvested in continental Asia (China) or Japan. China, as part of the continental mainland, and Japan are of different geological age. All Chinese coating films have an $^{87}\text{Sr}/^{86}\text{Sr}$ isotope ratio over 0.7100, and Japanese urushi films have a ratio of less than 0.7100; the borderline is around $^{87}\text{Sr}/^{86}\text{Sr} = 0.7100$.

A wood sample from the original artefact reused on the desk might be helpful as well, or a high-resolution CT scan of all the drawers of the desk for identification of wood species. Such wood can provide valuable
Because wood is everywhere, it is unnecessary to transport. Therefore there is reason to assume that locally available wood species were used regularly. That is why information on wood species is essential. For example, *hinoki* and *asunaro* (*Thujopsis dolabrata*, or *Hiba arborvitae*) are endemic in Japan. However, in this particular case, original wood is unlikely to remain in large volume, because it was probably almost completely removed before the process of adhering the *urushi* coating to the curved surfaces. Therefore, on sampling, it might be challenging to target precisely the right spot. With a high-resolution CT scan, the issue of sampling can perhaps be solved.

The blue colour of the panels on the desk is fascinating mainly since it has been encountered only on very few artefacts, but also because it has been assumed that the set of furniture was once located in the queen’s blue room. Blue urushi in combination with golden ormolu fittings also corresponds to symbols of the Swedish kingdom, both the flag and the national coat of arms, the latter used since 1448.

Reading historical documents either as original handwritten manuscripts or as digital copies of the same, creates several difficulties. It is a very time-consuming activity. Many documents have disappeared over time while others remain unrecorded and impossible to locate. Archival sources in Sweden are voluminous, so in practice, it is impossible to read even a minute fraction of the total. Handwriting can be illegible and digital copies even harder to decipher because

Figure 32. The specimen HGK1249 No. 2 shows gold leaf on the surface.

Figure 33. XRF microscopy of the specimen HGK1249 No. 2 same as in the previous figure. The presence of gold (Au) and copper (Cu) in less quantity, are confirmed.

Figure 34. Quantitative analysis of the backscattered X-ray emission of the specimen HGK1249 No. 2.
of the many archaic words and expressions. This study shows that the supply of imported Asian products in Europe, as well as in the Swedish market, was perhaps more than satisfactory. The speculation that artefacts were sent abroad to be covered with urushi needs to be substantiated. As far as is known, no scholarly research refers to such evidence. Whether or not urushi workshops existed in Europe at the time in question was out of the scope in this study. To be supported, further research needs to present trustworthy evidence, and the postulate remains unconvincing until then.

With the passage of time and exposure to daylight coatings are prone to deteriorate, decreasing in volume and gloss (Kamiya et al. 2006, 1311–1315; Honda 2017, 53–54). However, due to the detection of drying oil in the urushi layers on this set of furniture, the entire surface was probably not meant to be shiny. Therefore, to ‘restore’ gloss that did not exist in the first place is an overzealous and a misguided measure. To do it with synthetic or epoxy resin may jeopardise the long-term preservation and to limit possible alternatives for the future.

Conclusions
For several reasons it is possible to conclude that the black looking elements integrated into the set of furniture are made with urushiol and laccol saps. Some of their composition and manufacturing characteristics confirm that they probably are Japanese; especially the hinoki wood from the étagère is a strong indication (or even evidence) but also the fact that the mixture of saps in the desk shows affinity with historical artefacts from the Ryukyu Islands. If the original urushi ware can be dated between 1609 and mid-eighteenth century, it was manufactured when the Ryukyu Islands were under the Japanese ruler Shimazu. The character of the ground on the étagère (i.e. components and stratigraphy) indicates perhaps a Japanese origin, but there...
is a wide scope for interpretation. The ground on the
desk shows affinity with a simplified working process
with a mid-layer of paper that obviously existed in par-
allel with more elaborate structures. There is no evi-
dence that a folding screen used as wainscot in the
Chinese Pavilion also provided material for one or
both of the two-piece set of furniture. Hence, the
Pearl River motif in the yellow room has probably
little to do with the urushi components on the
décor. The hypothesis that it partly was completed
abroad is refuted. Dahlin’s furniture is similar to
many other contemporary Rococo taste furniture
including Oriental ware, and Parisan furniture
examples made around or just after the mid-eight-
eenth century were particularly skilful. Nevertheless,
the desk appears unique since it has blue coloured
urushi ware panels. Due to the general understanding,
especially of export urushi ware as typically black,
closer examination may be necessary to reveal other
possibilities. The present result might raise the aware-
ness of a broader colour spectrum than hitherto
anticipated.

Abbreviation

Sources of cited archival documents available phys-
ically or/and online.
GUB Göteborgs universitetsbibliotek the Gothenburg
University Library.
RA Riksarkivet the Swedish National Archives.

Notes

1. RA, St Petri kyrkoarkiv, Födelse- och dopböcker.
2. RA, Swedish East India Company archive, GUB, Special
collections, written documents, Ostindiska kompaniet.
3. RA, Forståliga personers räkningar, Statskontoret, Kam-
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